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Abstract. A 40-ac harvested loblolly pine (*Pinus taeda* L.) stand in the Lower Georgia Piedmont was divided into five randomized blocks, each containing four, 2-ac treatment plots. Treatments were: (1) herbicide followed by burning, (2) herbicide alone, (3) drum chopping, and (4) control. Herbicide application consisted of a Garlon 4TM and Tordon 101TM mixture applied with ground equipment in July 1987. Burning was done in September 1987. Chopping with an offset roller drum was completed in July 1987. Loblolly pine seedlings were planted in February 1988 and measured after one, two, and three growing seasons. After 3 years, mean height, diameter and volume index of the seedlings planted after herbicide application and burning were significantly larger than those on any other treatment area. Seedlings on plots treated only with herbicide were taller and had a higher volume index than seedlings on mechanically chopped plots and control plots. There was no significant difference in pine seedling survival among treatments. These results indicate that herbicide application followed by burning is an effective way for landowners to regenerate neglected cutover sites.

Introduction

Low-cost, effective procedures to regenerate loblolly pine (*Pinus taeda* L.) after harvest may be the key to reversing the decrease in the acreage of well-stocked pine stands in Georgia. Too often, nonindustrial private forest (NIPF) landowners cut mature stands of loblolly pine, realize a substantial income, but fail to make any effort to regenerate the harvested area to loblolly

pine. If, fortuitously, some pine regeneration becomes established and successfully competes with the hardwood vegetation, a mixed pine-hardwood stand may develop. After two or three similar cutting cycles, however, the pine component is virtually eliminated and cull or low value hardwoods dominate the site.

Sites can be prepared mechanically, chemically, by burning, or through combinations of these methods. Intensive mechanical site preparation, such as rostraking, windrowing, and disking increases early growth of planted pines (Lantagne and Burger 1987; Edwards 1990). It reduces woody competition and creates exposed soil conditions like those of abandoned agricultural land. Mechanical site preparation, however, often costs more than NIPF

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landowners are willing to invest in pine regeneration (Straka et al., 1989) and can cause site deterioration (Mitchell 1988).

Herbicide applications for site preparation have gained wide acceptance in the past decade (Merck 1989). The obvious advantage of chemical site preparation is minimal soil disturbance. A disadvantage is that even though the vegetation is killed or severely affected by the herbicide, a large amount of standing debris remains on the site making a difficult planting job. In addition, some plant species may resist the herbicide used and survive to compete with planted pine.

Fire is the classic site preparation method for replanting harvested southern pine sites. The use of prescribed fire throughout the rotation can eliminate or greatly reduce hardwood competition (Jones 1989). And broadcast burn after logging can dispose of much of the logging debris. The large amount of available fuel at that time can carry an intense enough fire to kill the tops of fairly large residual hardwoods. One disadvantage of burning after logging is that the logging operation disrupts fuel continuity so that a fire may not carry over the entire area.

Combinations of mechanical and fire treatments such as drum chopping and broadcast burning or felling and burning can be very effective. Herbicide and fire combinations also have synergistic effects (Clawson 1989). The correct herbicide will kill or severely damage much of the hardwood and herbaceous vegetation, increasing the amount of fuel available to carry a fire. Thus, the fire is more likely to burn through areas of understory vegetation that would not burn without prior herbicide treatment. Dead fuels created by applying herbicide also make ignition easier and permit burning on days when the fire hazard is relatively low.

The study described here was established to evaluate three postharvest site preparation alternatives that are commonly used by NIPF landowners in the Georgia Piedmont. The study was located on private land near the Ernst Brender Demonstration Forest in Jones County, Georgia, so that tour groups could compare these regeneration methods with preharvest site preparation alternatives as reported in these proceedings (Wade et al., 1991).

Methods

The study was installed on an area where the pine sawtimber and pulpwood had been harvested in 1985. By 1987, residual understory and overstory hardwoods dominated the site, and hardwood sprouts, weeds, and vines were well established. In July 1987, five randomized blocks of 8-ac each were delineated and the following four treatments assigned: (1) herbicide application followed by burning (brown and burn); (2) herbicide only; (3) drum chopping; and (4) control. Each treatment plot was approximately 2 ac in size. A 0.2-ac measurement plot was located in the center of each 2-ac treatment plot to measure development of seedlings to be planted after treatment applications. A concentric 0.02-ac plot was established to record the growth of understory stems greater than 4.5 ft tall but less than 4.6 inches in diameter.

Herbicide was applied with a tractor-mounted sprayer on July 16-17, 1987. The equivalents of ½ gal of Garlon 4TM and 1½ gal of Tordon 101TM were applied per acre (products registered by Dow Chemical Company). A spreader/sticker (Cide-kick) was mixed with the water solution. Approximately 25 gal of solution were applied per acre by making seven single passes across the 2-ac treatment plot with a 40-ft distance between passes.

Burning was done to the five scheduled plots on September 18, 1987. A front crossed the site during late morning, producing nearby rain showers but not on the study area. Burning conditions were marginal when the first plot (Block V) was ignited at 1245 but improved steadily during the afternoon. At ignition, ambient temperature and relative humidity were 86°F and 59 percent, respectively, and wind speed was 3-4 mph with gusts to 8 mph. Burning conditions peaked at 1600, when the temperature reached a maximum of 92°F, relative humidity stood at 42 percent, and winds were fairly steady at 5-6 mph. Moisture contents ranged from 6 to 9 percent in the upper litter layer and from 13 to 15 percent in the herbicide-treated hardwood foliage. The nearest fire weather station (about 7 mi distant) recorded a 1-h timelag fuel moisture of 9.5, a 10-h timelag fuel moisture of 9.0, and a fuel stick reading of 9. The Keetch-Byram Drought Index stood at 617, indicating the area was in severe drought. Plots were first back-fired and then ringed to produce hot fires. Fuel loading varied from virtually none to jackpots of several tons. Because of the wide variation in fuel loading and the firing techniques used, rates of spread were not methodically taken but spot measurements showed that they often exceeded 1 ft/min. Flame lengths of 6 inches to 3 ft were common except in jackpots, where they ranged up to 10 ft. Small areas on all plots contained thick, weedy growth that did not burn well. These patches and other areas the fire did not reach because of fuel discontinuities were ignited on September 19, so that 80-90 percent of each plot area was burned. All burns met the intended treatment objectives; results on Blocks II and III were judged excellent.

The chopped area received a single pass with an offset drum chopper pulled by a rubber-tired skidder.

Improved loblolly pine seedlings from the Georgia Forestry Commission nursery were hand planted on all treatment areas in February 1988 at a spacing of approximately 10 x 6 ft (726 trees/ac). Numbered tags were placed on pins set near each of the 140-150 planted seedlings in a 0.2-ac measurement plot. All volunteer seedlings were removed from measurement plots at the time of planting. Survival, height, and diameter (1.0 ft aboveground) of the planted pines were measured in October 1988 (survival and height only), January 1990, and October 1990.

Herbs, shrubs, vines, and trees less than 4.6 ft tall were observed on 10 permanent milacre plots per treatment plot. The 10 milacres were located on a line tangent to the 0.2-ac circular plot. The line was oriented in the plot to run perpendicular to the slope, and the milacres were 10 ft apart along the line. Coverages by vines, weeds, and grasses were estimated as percentages of the milacre. The total coverage for these three groups could exceed 100 percent due to layering of the vegetation. Also,

the four most important plant species identified on each milacre. To qualify, a species had to cover 10 percent or more of the area. For each identified plant, the percent cover was estimated.

The SAS/STAT (1987) software program for personal computers was used to analyze the data. Treatment means were separated with the Duncan's multiple range test when analyses of variance showed significant treatment differences at the 0.05 level of probability.

Results And Discussion

No significant difference in the survival of planted seedlings was found among site preparation treatments. After one, two, and three growing seasons overall survival was 69, 68, and 67 percent, respectively (Table 1). Thus, the greatest seedling mortality occurred from the time of planting in February 1988 until January 1989, when initial survival counts were recorded. A severe drought in the spring and early summer of 1988 was undoubtedly responsible for much of the mortality. Once established, however, planted seedlings on all plots maintained a stocking level of approximately 500 trees/ac for the next 2 years.

After the first growing season the heights of planted seedlings in the brown-and-burn area were significantly taller than those in the chopped or control areas (Table 1). By the end of the second growing season, seedlings on the brown-and-burn area were significantly taller than all other seedlings. By the end of the third growing season, the mean heights of seedlings in all treatments were significantly different: average heights were 5.98 ft on brown-and-burn area, 5.17 ft on the herbicide-only area, 4.59 ft on the chopped area, 4.00 ft on the control plots.

The diameter growth response of seedlings to treatment was similar to the height growth response. After two growing seasons, the mean diameter of the seedlings in the brown-and-burn areas was significantly greater than that of seedlings on any other areas (Table 1). After three growing seasons, the seedling diameters in the brown-and-burn area averaged 1.02 inches compared with 0.76 inch for the herbicide-only area, 0.72 inch for the chopped area, and 0.47 inch for the control area.

A seedling volume index can be computed by squaring the diameter and multiplying by the height. This value is useful for comparing pine seedling response growth among the treatment effects. For the 2 years with diameter measurements, the volume index after the brown-and-burn treatment was significantly greater than after any other site preparation treatment (Table 1). Both herbicide alone and the chopping also increased seedling growth over that of controls. The magnitude of the difference among treatments is striking. After three growing seasons, the volume index for seedlings in the brown-and-burn areas was more than six times that on the control area and more than twice that of the chopped area.

The outstanding response to the brown-and-burn treatment appeared to be a function of reduced competition during the first 3 years after planting.

Table 1. Survival, height, diameter, and volume index of loblolly pine seedlings planted on four site preparation treatments in the Georgia Piedmont.

Treatment	Year 1	Year 2	Year 3
----- Survival (percent) -----			
Brown and burn	71.87 a ¹	70.63 a	70.50 a
Herbicide only	65.18 a	64.02 a	62.88 a
Drum chopping	67.72 a	67.03 a	66.08 a
Control	73.61 a	71.48 a	69.22 a
----- Height (ft) -----			
Brown and Burn	1.16 a	3.52 a	5.98 a
Herbicide only	1.10 ab	2.89 b	5.17 b
Drum chopping	1.03 b	2.62 bc	4.59 c
Control	1.03 b	2.31 c	4.00 d
----- Diameter (inches) -----			
Brown and burn	--	0.59 a	1.02 a
Herbicide only	--	0.41 b	0.76 b
Chopping	--	0.39 b	0.72 b
Control	--	0.28 c	0.47 c
----- Volume index (inches ³) -----			
Brown and burn	--	21.88 a	102.99 a
Herbicide only	--	8.74 b	53.57 b
Drum chopping	--	7.27 b	43.39 c
Control	--	2.94 c	16.39 d

¹ Values with different letters within the same year are significantly different at the 0.05 level of probability.

Data from the 10 milacre samples per treatment plot in year 1 indicated that the percent cover of vines was significantly reduced on both the brown and burn plots and the herbicide only plots as compared to the chop treatment area or the control (Table 2). The pattern of increased vine competition on the chopped and control plots held for the next 2 years, but all plots showed an increase in the percent of vine cover from years 1 to 3.

Table 2. Percent cover of weeds and grasses and vines on milacre plots on areas with four site preparation treatments.

Treatment	Year 1	Year 2	Year 3
------(percent cover) -----			
Weeds and grasses			
Brown and burn	52.56 b ¹	66.72 a	53.80 a
Herbicide only	64.04 a	8.78 a	53.14 a
Drum chopping	43.74 b	61.74 a	40.76 ab
Control	44.78 b	45.90 b	31.74 b
Vines			
Brown and burn	19.18 b	39.28 c	33.68 c
Herbicide only	20.44 b	52.04 b	50.24 b
Drum chopping	56.52 a	78.02 ab	71.48 a
Control	53.30 a	84.10 ab	76.12 a

¹ Values with different letters within the same year are significantly different at the 0.05 level of probability.

In contrast, weed and grass species had a greater percent cover on the herbicide-only and brown-and-burn areas (Table 2). The herbicide-alone mean value in year 1 was significantly greater than those of the other three treatments. In year 2, the control treatment had a significantly lower percent cover value. In year 3, the brown-and-burn and herbicide-alone areas had significantly higher cover percentages than the control area, but they were not different from the chopped area.

Thus, weed and grass coverage was inversely proportional to the vine coverage. When vines were reduced by herbicide or herbicide and burning, the earlier species of plant succession are favored for 2 or 3 years. Planted pines compete more successfully with grasses than they do with vines and they grow faster in both height and diameter under the former conditions.

Individual plant species were recorded on each milacre plot when they occupied more than 10 percent of the area. The frequency and percent cover for important species were affect by site preparation treatments. For example, fireweed (*Eupatorium album* L.) is an aggressive pioneer species and was most prevalent after brown-and-burn or herbicide-only treatments (Table 3). In year 1, fireweed was identified on 80 percent of the brown and burn plots and 44 percent of the herbicide plots. However, only 2 percent of the chopped plots and none of the control plots had fireweed listed as an important species. In year 2, the percent of milacres with fireweed decreased to 2 and 6 percent in the brown-and-burn plots and herbicide-only

plots, respectively. Fireweed completely disappeared by year three on all plots. It was never observed as an important species on the control plots.

Table 3. Percent of milacres with indicator species, and the average milacre coverage for four site preparation treatments in the Georgia Piedmont.

Treatment	Year 1		Year 2		Year 3	
	Present	Cover	Present	Cover	Present	Cover
----- (percent) -----						
Fireweed						
Brown and burn	80	31	2	23	0	0
Herbicide only	44	27	6	22	0	0
Drum chopping	2	10	0	0	0	0
Control	0	0	0	0	0	0
Broomsedge						
Brown and burn	8	29	12	32	32	35
Herbicide only	30	22	56	37	60	38
Drum chopping	12	16	30	24	30	20
Control	8	21	28	20	22	25
Panicums						
Brown and burn	18	21	50	37	52	33
Herbicide only	34	28	42	35	26	23
Drum chopping	14	35	20	26	14	29
Control	28	17	32	39	22	32
Honeysuckle						
Brown and burn	14	47	38	55	52	46
Herbicide only	54	32	80	64	80	61
Drum chopping	82	58	100	76	92	74
Control	90	52	100	79	98	74

Other important species, such as broomsedge (Andropogon virginicus L.) and panicum grasses (Panicum spp.), were prevalent after all treatments and their occurrence was not related to the method of site preparation.

Broomsedge appeared to be favored by the herbicide-only treatment. Tordon 101 contains 2,4-D, which kills broadleaf weeds. Panicums were broadly found across all treated areas, but were not frequent on the brown-and-burn plots in years 2 and 3. This species invades disturbed sites and is favored by treatments that produce areas of bare soil. The presence of honeysuckle (*Lonicera japonica* Thunb.) was greatly reduced on the brown-and-burn plots in year 1 (14 percent), but its occurrence gradually increased to 52 percent of the plots by year 3. In contrast, both the chopped area and the control area had a high frequency of honeysuckle in year 1 (82 and 90 percent, respectively) and reached 100 percent occurrence by year 2 (Table 3). When present, honeysuckle tended to occupy a relatively large percentage of the site. For example, on control milacres honeysuckle coverage averaged 79 percent in year 2 and 74 percent cover in year 3.

The number of hardwood sprouts on the 0.02-ac plots was not significantly affected by site preparation method after three growing seasons. Sprout prevalence did not appear to be affected by treatment.

Conclusions

Planted loblolly pine responded very positively to a postharvest site preparation combination of herbicide and burning. Herbicide alone and mechanical treatment also increased seedling growth.

Pioneer plant species were favored by the brown-and-burn and herbicide-only treatments. For example, fireweed was prevalent the first 2 years after site preparation but disappeared from the plots by year 3. In contrast, vines were most prevalent after chopping and on untreated control areas. Vine coverage increased on the mechanical and control areas and by year 3 were the major species group on the plots.

When NIPF landowners harvest pine without a regeneration plan and the site is not adequately stocked with advance regeneration, the brown-and-burn site preparation method can be effectively used to establish a fast-growing pine plantation.

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